3.3 Work, energy and power

Words like *energy*, *power* and *work* have very precise meaning in physics. In this section the important link between work done and energy is explored. Learners have the opportunity to apply the important principle of conservation of energy to a range of situations. The analysis of energy transfers provides the opportunity for calculations of efficiency and the subsequent evaluation of issues relating to the individual and society (HSW2, 5, 8, 9, 10, 11, 12).

3.3.1 Work and conservation of energy

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	Learning outcomes	Additional guidance
	Learners should be able to demonstrate and apply their knowledge and understanding of:	
(a)	work done by a force; the unit joule	
(b)	$W = Fx \cos\theta$ for work done by a force	
(c)	the principle of conservation of energy	HSW2
(d)	energy in different forms; transfer and conservation	
(e)	transfer of energy is equal to work done.	

(6) M - State the different forms of energy and the law of conservation of energy
(7) S - Apply the law of conservation of energy to energy transfer situations
(8) C - Define and calculate 'work done' incluing forces at an angle.

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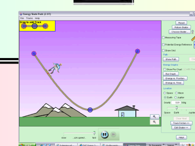
Work and conservation of energy

STARTER: How many type of energy can you name? Where is this energy found?

Extension: What else do you know about energy?



- Energy is 'capacity' to do 'work'.
- It is scalar, so has magnitude but not direction
- The SI unit in the Joule (same as **work** done)
- **Principle of conservation of energy**: The total energy of a closed system remains constant - energy cannot be created or destroyed, only transferred from one form to another

Ex: What is the SI base unit?

Form of energy	Description	Examples
kinetic energy	energy due to motion of an object with mass	moving car moving atoms
gravitational potential energy	energy of an object due to its position in a gravitational field	child at the top of a slide water held in clouds
chemical energy	energy contained within the chemical bonds between atoms – it can be released when the atoms are rearranged	energy stored within a chemical cell energy stored in petrol and released when it is burnt
elastic potential energy	energy stored in an object as a result of reversible change in its shape	a stretched guitar string a squashed spring
electrical potential energy	energy of electrical charges due to their position in an electric field	electrical charges on a thundercloud static charge on a charged balloon

Form of energy	Description	Examples
nuclear energy	energy within the nuclei of atoms – it can be released when the particles within the nucleus are rearranged	energy from fusion processes in the Sun energy from nuclear fission reactors
radiant (or electromagnetic) energy	energy associated with all electromagnetic waves, stored within the oscillating electric and magnetic fields	energy from the hot Sun energy from an LED
sound energy	energy of mechanical waves due to the movement of atoms	energy emitted when you clap output energy from your headphones
internal (heat or thermal) energy	the sum of the random potential and kinetic energies of atoms in a system	a hot cup of tea has more thermal energy than a cold one

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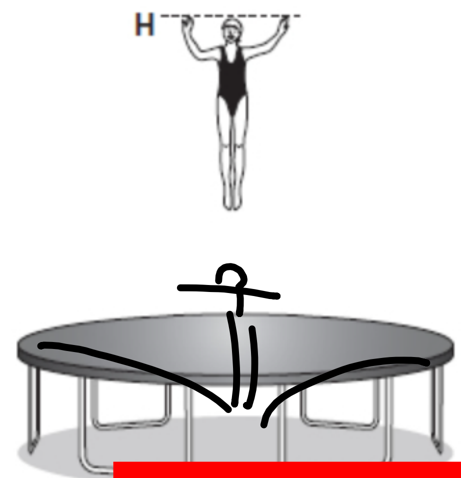
Principle of conservation of energy

Principle of conservation of energy: The total energy of a closed system remains constant - energy cannot be created or destroyed, only transferred from one form to another

1. What is the relevance of a 'closed system'?
2. Can you come up with an example of one?
3. Describe and explain the energy changes involved as the girl bounces from position **H** and back to the same position shown in the diagram. **a)** firstly assuming this is a closed system. **b)** assuming that this is not a closed syste



- GPE to KE to EPE then...
- EPE to KE to GPE
- Energy losses due to work done on trampoline in landing
- Work done by child on trampoline = to energy losses
- Thermal energy remains in person or trampoline.

- GPE to KE to EPE then
- EPE to KE to GPE
- Energy losses due to work done on trampoline in landing / work done on air
- Work done by child on trampoline = to energy losses
- Thermal energy lost to surroundings

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(8) C - Define and calculate 'work done' including forces at an angle.

Nm

OR

J

Work done

N m

Work done =force x distance moved in the direction of the force

What are the units for each quantity?

[redacted]

1 Joule = 1 Nm

e.g. 1 joule is defined as the work done when a force of 1N moves its point of application 1m in the direction of the force.

[redacted]

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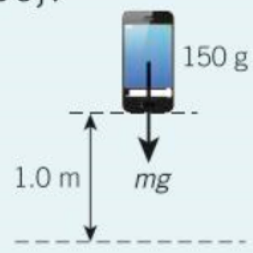
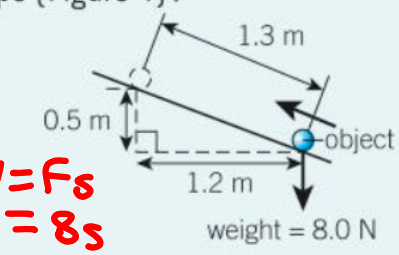
Quick check - Calculate the work done.

1. a phone falling freely to Earth (Figure 3)?



▲ Figure 3

2. an object being moved up a smooth slope (Figure 4)?



W=Fs
W=8s

▲ Figure 4

The force acting on the object is its weight *mg*. $W = Fx$ $W = (0.150 \times 9.81) \times 1.0$ $= 1.5$ J (2 s.f.) The work done **by** the force of gravity on the object is transferred to kinetic energy.	The distance travelled in the direction of the force (the weight) is 0.5 m, and not 1.3 m nor 1.2 m. $W = Fx$ $W = 8.0 \times 0.5 = 4.0$ J The work done **against** the force of gravity is transferred into gravitational potential energy.

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Work done at an angle

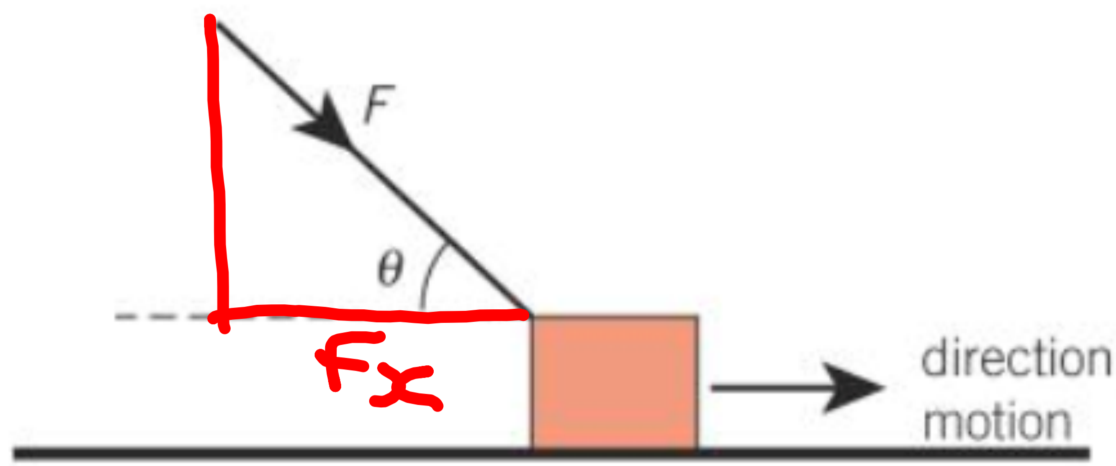
Often the direction of motion and the force are not in the same direction.

In this case the component of the force acting in the direction of motion is needed to find the work done.

$W = Fs$

$W = F_x s$

$\boxed{W = F\cos\theta\, s}$



1. Sketch the diagram.
2. Add the horizontal component of F
3. Write the general equation for work done

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ACTIVITY: Complete the summary questions on pages 73 and 75.

Extension:

https://physics.info/work/problems.shtml

make worksheet fro mthese problems

3 Calculate the work done by a person of mass 60 kg to climb to the top of a 5.8 m wall. *(2 marks)*

4 A shopper pushes a 38 kg shopping trolley at a constant speed up a car park ramp. The ramp is at 10° to the horizontal and is 3.1 m long. Calculate the work done to push the trolley to the top of the ramp. *(3 marks)*

5 A person exerts a force of 65 N at 52° to the horizontal floor to push a box 5.0 m across a floor at constant speed. Calculate the work done on the box. Explain, in terms of energy, what happens to the work done on the box. *(3 marks)*

6 A bullet travels straight through a piece of wood of thickness 30 mm. The change in the kinetic energy of the bullet is 1.4 kJ. Calculate the average force exerted by the wood on the bullet. *(4 marks)*

Summary questions

1 **a** State what is meant by the term *potential* in physics. *(1 mark)*
b State the energy changes taking place when you rub your hands together. *(1 mark)*

2 A lamp converts 20 J of electrical energy into 5 J of light energy and one other form of energy. Suggest what this other form of energy is, and calculate its quantity. *(2 marks)*

3 Describe the useful energy conversions that happen in:
a a filament lamp; *(1 mark)*
b the headphones connected to a mobile phone. *(1 mark)*

4 A car is travelling on a level road at constant speed. Figure 4 is a visual representation of the energy conversions of the chemical energy in the fuel – the diagram is called a Sankey diagram.
a Explain why the diagram does not show the kinetic energy of the car. *(1 mark)*
b Calculate the percentage of total energy wasted as thermal energy. *(1 mark)*

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Plenary - Try this PPQ

c A trolley of mass 80 kg is being pulled by along a horizontal path. Figure 1b shows the force, *T*, exerted on the trolley and the frictional force, *F*, acting between the trolley and the path.

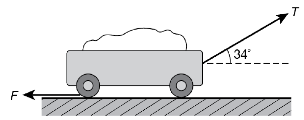

Figure 1b

i In order to keep the trolley moving at a constant speed of 0.85 m s^{-1}, a force of 120 N is exerted at an angle of 34° to the horizontal. Calculate the frictional force, *F*.

F = ... N (*1 mark*)

ii Calculate the work done to pull the trolley a distance of 75 m.

work done = ... J (*1 mark*)

iii After travelling 75 m, the trolley is no longer pulled. Explain why the trolley continues to roll forward and calculate the distance you would expect the trolley to travel. State any assumptions you have made in determining this distance.

(4 marks)

$W = Fs$

$s = \frac{W}{F} = \frac{KE}{\text{Friction force}}$

MS

1 c i	$F = 120 \times \cos 34 = 99.4$ N	A1	Many students muddle sin and cos.
1 c ii	Work done = $120 \times 75 \times \cos 34 = 7.46 \times 10^3$ J	A1	Only the horizontal component of *T* does work on the trolley.
1 c iii	Trolley possesses kinetic energy and will continue to move until this is all dissipated as thermal energy (work done against *F*). $E_k = \frac{1}{2} \times 80 \times (0.85)^2 = 28.9$ J Extra distance = $\frac{28.9}{99.4} = 0.29$ m Assume *F* is constant/independent of speed	B1 C1 A1 B1	Because it is necessary to use the answer to part **i** here, **allow** an e.c.f. provided all working is shown.

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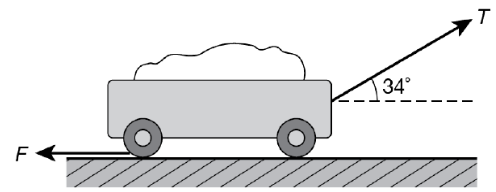

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(4 marks)